Beta and theta oscillatory dynamics in response to social evaluative feedback processing: Neural markers of anxious temperament?

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ABSTRACT
Electrocortical activity to processing social evaluative feedback differed in individuals with distinct profiles in rejection sensitive personality constructs. 65 undergraduate females participated in the Social Judgment Paradigm in which they predicted if peers liked or disliked them. With EEG, beta (13-30 Hz) and theta (4-8 Hz) power was examined, which are related to anticipation of and sensitivity to social feedback, respectively. We detected an anxious and a non-anxious group. Beta power increased in anticipation of social feedback. Theta power was highest for unexpected rejection. Beta activity reflects anticipation of rejection, whereas theta power is a neural signature of unexpected rejection.

Keywords
Beta power, EEG, rejection sensitivity, social feedback, theta power.

INTRODUCTION
Relationships with others are needed for someone's well-being and survival according to an evolutionary standpoint.[1] If others accept you, then you belong to the group and have higher chances of surviving. In the case of a social threat, i.e. when others reject you, you experience social pain. This shows that social feedback has a central role in interpersonal functioning. Individuals differ in how they respond to social feedback, but this remains largely understudied. In this study, these individual differences in social feedback processing were examined by looking at individuals with different levels of rejection sensitivity, which were determined by three rejection sensitive personality constructs: attachment style, fear of negative evaluation and self-esteem. This knowledge is important as rejection has severe consequences and hypersensitive individuals may be more vulnerable to these consequences.[2,3] Regarding the attachment style as the first construct, three attachment styles can be differentiated based on the qualitative aspects of the interactions between the child and parents that determine the expectations the child has about the self and about how others in the future likely will treat him or her.[4,5] According to this attachment theory, the three styles are the secure, anxious and avoidant attachment. It is thought that anxiously attached individuals are hypersensitive to social feedback, whereas avoidantly attached individuals are hyposensitive because of their attachment system.[5,6] Fear of negative evaluation, which implies negative self-evaluations and biased information processing regarding social situations, is the second rejection sensitive personality construct.[7] Higher levels on this construct are also associated with higher levels of social anxiety.[8] Finally, self-esteem is related to rejection sensitivity as it is strongly implicated in social anxiety and fear of negative evaluation.[7]

fMRI studies have already shown differences in brain activity between individuals with high vs. low rejection sensitivity, which was specifically based on the attachment style. As for the two brain regions that show activation in reaction to social exclusion, there was heightened activity for people with an anxious attachment and reduced neural activity for avoidantly attached people.[1,2] We wanted to broaden the understanding of these neural correlates by investigating the electrocortical activity prior to receiving social feedback, by examining beta power which is related to anticipatory processes[9], as well as after receiving feedback, by looking at theta power which is implicated in the processing of social feedback.[10]

Thus, we investigated whether the neural correlates of the anticipation and processing of social evaluative feedback differed between individuals with distinct profiles of rejection sensitivity, i.e. anxiety regarding social feedback. We hypothesized that less anxious participants would predict a larger proportion of social acceptance feedback, whereas more anxious individuals would predict a larger proportion of social rejection feedback as they would have more negative appraisals about themselves in social situations.[6] With respect to beta power during feedback anticipation, it was expected that beta power in anxious individuals would be more pronounced than in less anxious individuals while expecting social rejection. As it is argued that beta

SRC 2016, November 30, 2016, The Netherlands.

power might be related to pain anticipation and that physical and social pain have shared neural underpinnings, heightened beta power in anxious individuals may reflect increased arousal regarding anticipated social rejection.[1,11] Lastly, with respect to processing of social feedback, it was thought that theta power would be significantly increased when participants received unexpected rejection feedback.[10] It was expected that theta power would be highest in anxious individuals, as they would be the most hypersensitive to social signals.[6]

METHOD

65 healthy female first year students between the ages of 18 and 25 were recruited. We used a cluster-analysis to create groups. This data-driven approach detects clusters based on which of the variables, i.e. attachment style, fear of negative evaluation and self-esteem, were the best predictors. These constructs were measured by three self-report questionnaires: Experiences in Close Relationships questionnaire (ECR), Brief version of Fear of Negative Evaluation scale (BFNE-R), and Rosenberg Self-esteem Questionnaire (RSEQ), respectively.

We employed the Social Judgment Paradigm to investigate the processing of social feedback. In this task, participants are told that peers indicated earlier if they liked or disliked the participants at the first impression. Participants then have to predict if the peers would like them or not. After this choice, the participants get to see if their prediction is right. The feedback is in reality generated by a computer. Based on the expectations (Expectancy) and the feedback outcome (Valence), four conditions can be created: expected acceptance, expected rejection, unexpected acceptance and unexpected rejection.

During this paradigm, we looked at the beta and theta oscillatory power with EEG. The beta power was extracted from two feedback anticipation conditions (positive vs. negative expectations) during two separate time-bins (bin 1 = 2000-1000 ms pre-feedback; bin 2 = 1000-0 ms pre-feedback) and at two clusters of electrodes (sensorimotor vs. frontocentral cortex). We focused on the frontal electrodes during bin 2 as it was expected to find individual differences at this site in this time-bin. Theta power was examined at the Fz electrode during a 300-500 ms post-feedback window. The data were log-transformed for further statistical analyses.

RESULTS

The cluster analysis yielded two subgroups of 32 and 33 participants with a fair cluster quality of 0.4. The two groups differed significantly in fear of negative evaluation and in self-esteem, where one group scored higher on fear of negative evaluation and lower on self-esteem compared to the other group. The subgroups were labeled as being hypersensitive and hyposensitive to social feedback, respectively, and are hereafter referred to as anxious and non-anxious.

Expectations

It was investigated if the groups differed with respect to their expectancies about the social evaluative outcome. An independent samples test revealed that non-anxious participants did show an optimism bias as they expected social acceptance on 55.4% of all trials. This differed significantly from 50%, $t(32) = 3.65$, p = .001. Anxious participants also showed a positivity bias as they predicted acceptance on 52.9% of all trials, but this did not significantly differ from 50%, $t(31) = 1.82$, p = .078. So, only the non-anxious group explicitly displayed an optimism bias.

Beta power

With two One-way ANCOVAs, one per expectation (expected acceptance vs. rejection), it was investigated if there were differences in beta power during feedback anticipation between the two groups when controlling for the reaction times. This covariate was used to see to what extent possible effects were influenced by beta-related motor activity. For expected acceptance, there was no significant effect of the groups on beta power, $F(1, 62) = 3.10$, $p = .083$. $\eta_p^2 = .05$. For expected rejection, there was also no significant difference between the two groups on beta power, $F(1, 62) = 0.02$, $p = .893$. $\eta_p^2 = .00$. These effects were not influenced by the reaction times as these were non-significant for expected acceptance ($p = .818$) and for expected rejection ($p = .333$). The beta power from both groups can be seen in Figure 1. This shows that the anxious group had higher beta activity when expecting acceptance.

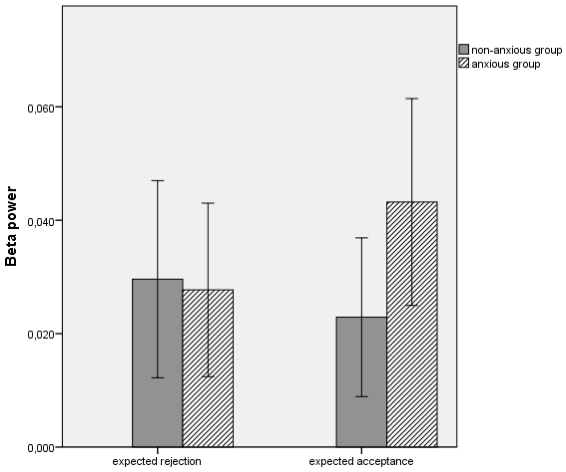

Figure 1: Means of the subgroups on the log-transformed beta power when expecting rejection and acceptance. Error bars denote standard error from the mean.

Theta power

A repeated measures ANOVA was performed to investigate differences in theta power between the four feedback conditions and subgroups. The

results indicated significant main effects for Expectancy, $F(1, 63) = 23.32$, $p < .001$. $\eta_p^2 = .27$, and for Valence, $F(1, 63) = 6.83$, $p = .011$. $\eta_p^2 = .10$, and significant interaction effects for Expectancy x Valence, $F(1, 63) = 4.84$, $p = .032$. $\eta_p^2 = .07$, for Expectancy x Group, $F(1, 63) = 5.93$, $p = .018$. $\eta_p^2 = .09$, and for Expectancy x Valence x Group, $F(1, 63) = 5.79$, $p = .019$. $\eta_p^2 = .08$. Follow up pairwise comparisons yielded the result that theta power was significantly higher for unexpected social rejection than for the other conditions. Separate repeated measures analyses were performed per group to examine the effects. For the non-anxious group, the repeated measures yielded a significant main effect for Valence, $F(1, 32) = 10.39$, $p = .003$. $\eta_p^2 = .25$, and a significant interaction effect for Expectancy x Valence, $F(1, 32) = 9.99$, $p = .003$. $\eta_p^2 = .24$. Follow up pairwise comparisons showed that theta power was significantly the highest after unexpected rejection than after the other conditions. For the anxious group, the results indicated a significant main effect for Expectancy, $F(1, 31) = 28.94$, $p < .001$. $\eta_p^2 = .48$. Follow up pairwise comparisons yielded the result that higher theta power is elicited after unexpected feedback than after expected feedback. The theta power in each condition in each subgroup can be seen in Figure 2.

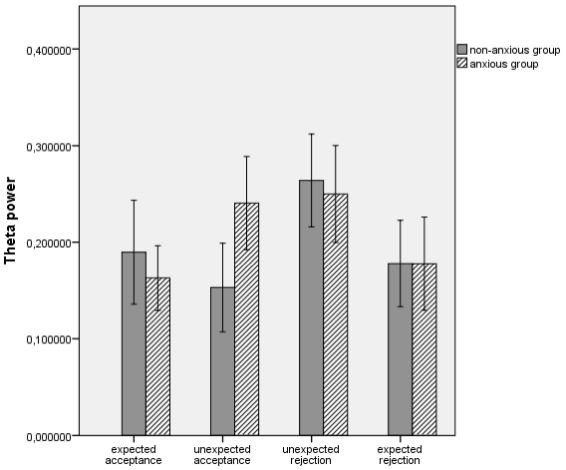

Figure 2: Means of the subgroups on the log-transformed theta power at Fz in each condition. Error bars denote standard error from the mean.

CONCLUSION

The goal of this research was to examine differences in electrocortical reactivity during a social evaluative feedback task and to examine individual differences in this reactivity related to rejection sensitivity. A cluster analysis yielded evidence of two groups that differed in fear of negative evaluation and self-esteem, where one group scored higher on fear of negative evaluation and lower on self-esteem than the other group. The groups are therefore interpreted as the anxious and non-anxious group, respectively. Main results indicated increased beta activity in anticipation of social feedback, especially for anxious individuals when expecting acceptance, and increased theta activity after unexpected rejection. Together, these findings suggest that these beta and theta oscillations to social evaluations can be regarded as neural markers for rejection sensitivity.

There was an optimism bias for the non-anxious individuals, but the anxious individuals still expected slightly more acceptance than rejection. This can be explained by the belongingness theory, as human beings have a strong internal need to belong and therefore orient themselves towards others as positively as possible.[12]

No significant differences were found between the anxious and non-anxious group in beta activity when expecting rejection as well as when expecting acceptance. It is thought that when expecting rejection beta power is related to the anticipation of the rejection. It has been found that beta power increases when the probability of a shock increases.[11] Because of the shared neural underpinnings for physical and social pain, it is likely that this mechanism of anticipation of physical pain is also reflected in beta activity when anticipating social pain.[1] Higher beta then implies increased arousal regarding the anticipation of social pain because of the severe consequences of social rejection.[3] In the anticipation of expected acceptance, the higher beta power for anxious individuals can be explained by the idea that beta may be related to uncertainty about the feedback.[7,13] As anxious individuals may think that acceptance by peers is more unlikely, e.g. higher fear of negative evaluation and lower self-esteem, they are more uncertain when they do think to be accepted. The absence of significant effects of the response latencies on beta power increases the likelihood that the observed beta activity reflects cognitive and socioemotional processes implicated in the anticipation of social evaluative feedback.

We found a significant increase in theta power after receiving unexpected rejection, which is consistent with previous findings.[10] Theta power can be considered as a neural signature of social rejection, which can be explained by the social belongingness theory: it is important to be included and to be accepted.[12] In the case of unexpected rejection, this need is not met which causes severe social stress. Thus, theta power is involved in the processing of signals that convey this social threat so that individuals can deal with the social rejection and with the possibility of social isolation if this continues. The results regarding theta power further indicated that for the non-anxious individuals theta power is the highest after unexpected rejection and that there is more theta power for the anxious individuals after unexpected than after expected feedback. So, an unexpected rejection effect exists for the non-anxious group

and only a congruency effect for the anxious group. The unexpected rejection effect previously found by others only seems to apply to the non-anxious group.[10] Both effects can be explained by the idea that the increase in theta power is mainly the result of the interaction between the expectancy violation and the actual outcome, but that the expectancy violation is sufficient to already create heightened theta power.[10,14]

Although this study yielded interesting findings regarding individual differences in the electrocortical reactivity in a social evaluation task, this study has a few limitations. Within the population of first year female students, it is possible that there are no strong extremes on the scores of the questionnaires and this might be an important factor that hampered finding significant differences in the attachment styles. The limited range of scores we found on all self-report questionnaires supports this notion. Also, the sample size was small, although subgroups of 32 and 33 participants are reasonable. Finally, all participants could on average be more anxious, as there is heightened sensitivity to social evaluation in late adolescence.

To conclude, this study has shown heightened beta oscillations in anticipation of social feedback, which reflect the anticipation of rejection and the uncertainty about the acceptance feedback, as well as heightened theta oscillations after unexpected rejection. Anxious individuals differ from non-anxious individuals in the anticipation and processing of social feedback. These findings add to a broader understanding of the neural underpinnings of individual differences in the processing of social evaluative feedback. Future research can further examine differences between the attachment styles, the specific mechanisms implicated in the beta power during anticipatory processes, and how individual differences in theta activity after receiving feedback have an impact on daily functioning in real-life situations. It could be related to normal vs. atypical social development.

ROLE OF THE STUDENT

Sophie Sweijen was an undergraduate student under the supervision of Dr. Melle J. W. van der Molen while working on this study in the year 2016-2017. The main topic, design and procedure of the research was proposed by the supervisor, whereas the specific topics, the statistical analyses and writing were done by the student.

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